What is claimed is:

Sub A1

1. A wavefront transformer suitable for transforming an incident electromagnetic wavefront having a given shape to a reflected wavefront having a different shape, comprising: a substrate having a conductive surface for reflecting the incident electromagnetic energy, and a plurality of openings in the conductive surface, each opening formed by a respective one of a plurality of discrete cavities extending from the conductive surface, each cavity having a selected position on the conductive surface with respect to the focal point to induce a propagation phase shift over the distance to the focal point, each cavity inducing a local phase shift in the reflected electromagnetic energy as a function of a selected dimension of the cavity, the combined propagation phase shift and local phase shift from the plurality of cavities places the reflected electromagnetic energy in phase at the focal point.

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2. A wavefront transformer as set forth in claim 1, wherein the substrate is a metal plate.

3. A wavefront transformer as set forth in claim 2, wherein the plate is substantially flat.

Sub A2

4. A wavefront transformer as set forth in claim 2, wherein the plate includes a first plate overlying a second plate, wherein the first plate has a plurality of through-holes therein that form the cavities and the second plate forms a flat bottom surface of the cavities.

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5. A wavefront transformer as set forth in claim 2, wherein the plate has a substantially uniform thickness.

6. A wavefront transformer as set forth in claim 1, wherein one or more properties of the cavities varies with position with respect to the focal point.

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7. A wavefront transformer as set forth in claim 6, wherein the properties that vary include dimensions of the cavities and spacing between neighboring cavities.

8. A wavefront transformer as set forth in claim 7, wherein the dimensions of the cavities include cross-sectional dimensions that include one or more of width, depth and radius.

9. A wavefront transformer as set forth in claim 1, wherein the plurality of cavities form a periodic array.

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10. A wavefront transformer as set forth in claim 1, wherein only the positions of the cavities and the selected dimension of the cavities varies, the dimension of each cavity is selected such that the total phase shift at the focal point of an electromagnetic wave reflected from each cavity is equal, so that

$$\phi(r) = \phi(0) + \frac{2\pi}{\lambda}\left(\sqrt{r^2 + f^2} - f\right),$$

where r is the distance of the cavity from a reference point in the plane of the conductive surface, $\phi(r)$ is the local phase shift imposed on an incident electromagnetic wave at r by the flat reflecting surface, f is the focal length of the reflector, λ is a desired wavelength of the reflected electromagnetic energy, and $\phi(0)$ is the local phase shift imposed on an incident electromagnetic wave by a cavity at the reference point having a dimension a(0,0).

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11. A wavefront transformer as set forth in claim 10, wherein the wavefront transformer has a focal length of about four and a half inches (about 11.4 cm).

12. A wavefront transformer as set forth in claim 10, wherein a(0,0) is a radius of a circular opening formed by a cylindrical cavity.

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13. A wavefront transformer as set forth in claim 12, wherein a(0,0) is about 44.5 mils (about 254 μm).

14. A wavefront transformer as set forth in claim 10, wherein the cavity dimension is selected for frequencies greater than about 20 GHZ.

15. A wavefront transformer as set forth in claim 14, wherein the cavity dimension is selected for a frequency of about 95 GHZ.

16. A wavefront transformer as set forth in claim 10, wherein the cavities have a uniform depth of about 100 mils (about 2.54 mm).

17. A wavefront transformer as set forth in claim 10, wherein the nearest-neighbor distance between adjacent cavities is uniform.

18. A wavefront transformer as set forth in claim 10, wherein the nearest-neighbor distance between adjacent cavities is about 105 mils (about 2.67 mm).

19. A wavefront transformer as set forth in claim 1, wherein the cavities have a depth that is less than a local thickness of the plate.

20. A wavefront transformer as set forth in claim 1, wherein the openings are circular.

21. A wavefront transformer as set forth in claim 1, wherein the cavities are cylindrical.

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22. A wavefront transformer as set forth in claim 1, wherein the plurality of cavities are arrayed in an equilateral-triangular arrangement.

23. A reflector suitable for focusing incident electromagnetic energy at an operating wavelength on a focal point, including the wavefront transformer of claim 1.

24. An antenna, comprising: the reflector of claim 23 and a waveguide feed located at the focal point.

25. A method of making a reflector suitable for focusing incident electromagnetic energy at an operating wavelength on a focal point, the wavefront transformer having a substrate with a conductive surface for reflecting the incident electromagnetic energy, and a plurality of openings in the conductive surface, each opening formed by a respective one of a plurality of discrete cavities extending from the conductive surface, the method comprising: selecting a dimension of each cavity as a function of a propagation phase shift and a local phase shift created by the cavity at a desired distance from the focal point, and forming the cavities in a conductive surface, wherein the dimension of each cavity is selected such that the local phase shift imposed on an incident electromagnetic wave is

$$\phi(r) = \phi(0) + \frac{2\pi}{\lambda}\left(\sqrt{r^2 + f^2} - f\right)$$

where r is the distance of the cavity from a reference point on the conductive surface, f is the focal length of the wavefront transformer, λ is a desired wavelength of the reflected electromagnetic energy, and ϕ(0) is the local total phase shift imposed on an incident electromagnetic wave at the reference point by a cavity having a dimension a(0,0).

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26. A method as set forth in claim 25, wherein forming the cavities includes forming the cavities in an equilateral-triangular arrangement.

27. A method as set forth in claim 25, wherein forming the cavities includes forming through-holes in a first plate and mounting the first plate on a backing plate that forms a solid bottom surface for each hole.

28. A method as set forth in claim 25, wherein forming the cavities includes machine reaming.

29. A method as set forth in claim 25, wherein forming the cavities includes using electronic discharge machining.

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30. An antenna suitable for focusing incident electromagnetic energy at an operating wavelength on a focal point, comprising: a geometrically flat wavefront transformer plate having a conductive surface and a waveguide feed positioned at the focal point suitable to receive the reflected electromagnetic energy; the wavefront transformer plate further includes a plurality of discrete cavities opening in the conductive surface, the dimensions of each cavity varying as a function of the position of the cavity on the plate with respect to the focal point to induce a local phase shift on the incident wave of electromagnetic energy as the electromagnetic energy is reflected, the cavities being spaced with respect to adjacent cavities to enable the wavefront transformer plate to focus the reflected electromagnetic energy at the focal point such that electromagnetic energy reflected from the wavefront transformer plate is in phase at the focal point.

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31. An antenna as set forth in claim 30, wherein the cavities are arrayed in an equilateral-triangular arrangement.

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32. A reflector suitable for focusing incident electromagnetic energy at an operating wavelength on a focal point, comprising: means for focusing an incident plane wave of any polarization at the focal point.

33. A reflector as set forth in claim 32, wherein the means for focusing includes a substrate having a conductive surface for reflecting the incident electromagnetic energy, and a plurality of discrete cavities having openings in the conductive surface, each cavity forming part of at least one equilateral-triangular arrangement of cavities.

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